THE EFFECTS OF INSTRUCTION AND STRATEGY IMPLEMENTATION ON INCREASING MATHEMATICS COMPUTATION SKILLS FOR STUDENTS WITH LEARNING PROBLEMS: A META-ANALYSIS

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It is well known by educators and researchers that students with a Specific Learning Disability (SLD) often do not make adequate progress when using traditional instructional methods (Whinnery & Stecker, 1992). Therefore, teachers must experiment with different techniques in order to help these students succeed. Many educational models and interventions have been introduced recently in an effort to help increase the level of math performance of at-risk and SLD students. The current meta-analysis study was conducted to determine the effects of instruction and strategy implementation on increasing mathematics and computation skills for students with learning problems and Specific Learning Disabilities. The results indicated that instruction and strategy implementation can increase mathematics computation skills for students with diagnosed Specific Learning Disabilities.

Chapter I

Introduction

Mathematics instruction has experienced significant change throughout the past fifty years as it relates to Special Education. This dramatic change has been in response to several factors. First and foremost is the increased awareness of students with Specific Learning Disabilities (SLD) in mathematics. Second, research has shown many difficulties found with the mathematics curricula throughout the elementary and middle schools (Rivera, 1997). Next, federal funding was increased and new policies and procedures have been implemented. Finally, technological advances have increased the number of ways the students can learn and the teachers can monitor instruction within the classroom.

Research findings have uncovered important information about the characteristics of students and/or children with Specific Learning Disabilities in mathematics and possible assessment strategies (Rivera, 1997). Students with Specific Learning Disabilities may lack the ability to acquire and/or apply the mathematical concepts and skills needed to accurately complete mathematics problems found within the traditional classroom curriculum (Rivera, 1997). The curriculum may not target every student's specific need in order for learning to properly take place; therefore, additional resources are needed to assist each student. Furthermore, these individuals often have insufficient cognitive strategies needed to learn efficiently (Bryant & Rivera, 1997). In this case, the student may need additional instruction outside of the regular education classroom to ensure understanding.

A student with a Specific Learning Disability may not be able to obtain the level of skills needed to compete with his or her typical same-age peers, possibly leading to devastating effects on the student's self-esteem and behavior. Based on the severity of the deficit, students exhibiting disabilities in mathematics require varying levels of educational support to accommodate their needs and allow them to create and use strategies of their own to learn the necessary skills.

Historical Trends in Mathematics Education

Based on historical trends, increased research and new findings, new laws, and technological advances throughout the twentieth century, mathematics education has changed dramatically. It has progressed from a basic focus on the rote acquisition of arithmetic facts and algorithms to presently include a more conceptual understanding using problem-solving activities, a constructivist emphasis

(Cumming & Elkins, 1999). From a retrospective look at the history of the field of mathematics education, the 1950s and 1960s were marked by a significant increase in federal funding to support the research for and the development of a specialized field in mathematics (Rivera, 1997). The funding and consequent change in education was intended to produce scholars, highly trained teachers, and graduates in mathematics, science, and engineering to assist in reinstating the United States as a world leader after Sputnik (Rivera, 1997). This change moved the curriculum away from the traditional focus on facts and procedures (Schoenfeld, 2002). Furthermore, it has been debated that these fast-paced reform actions caused even more students to fall behind their peers in academic areas (Bryant & Rivera, 1997).

The 1970's brought the Back to Basics movement to light and once again focused on teaching the students pure mathematics. During the 1980's, standardized testing movements indicated poor mathematics achievement in the United States. Scores on the testing showed a steady decrease in students' mathematical ability during the years from 1960 to 1985 (Fleischner & Manheimer, 1997). Students were obviously not gaining any more knowledge of the "basics" than had the students in the 50's and 60's

(Schoenfeld, 2002). During the 1980's, the curriculum changed to teaching more problem-solving based mathematics (Schoenfeld, 2002). Additionally, the National Council of Teachers of Mathematics began instituting reform efforts, including changes in mathematics curricula and instructional methods, and teacher preparation programs (Rivera, 1997). The problem-solving solution was replaced in the 1990's by a more standards-based mathematics approach (Schoenfeld, 2002).

Following along with the standards-based approach is the Individuals with Disabilities Education Act of 1997 (IDEA). An important element of the IDEA Amendments is that all students with disabilities must be provided that opportunity to learn alongside students without disabilities. This method also caused tremendous changes in education and the curriculum as a whole (Bottge, Heinrichs, Mehta, & Hung, 2002).

Overall, the field of mathematics education has changed several times over the past fifty years and continues to grow and change. At present, mathematics educators are using the theory that learning mathematics is based on a constructive process, in which gaining mathematical knowledge is an ongoing activity within the classroom environment (Rivera, 1997). The obvious main goal of each of the reform movements has been, and still is, to enable each student to obtain a well-rounded education in mathematics.

As previously stated, during the past few decades, learning disabilities, in all areas, have received increased attention from educational researchers, teachers, and evaluators. In fact, the term "learning disabilities" was officially coined in the early 1960s. Students with a Specific Learning Disability often do not make adequate progress when using the traditional instructional methods (Whinnery & Stecker, 1992). Overall, there is no one strategy of instruction alone that has proven to be effective for students that present a Specific Learning Disability. Due to the need for different strategies, teachers must experiment with several different methods in order to help the students succeed (Whinnery & Stecker, 1992).

Specific Learning Disabilities and interventions in the area of mathematics have not received as much attention in past years as Specific Learning Disabilities in reading and writing. This fact is true even though research has shown that a higher proportion of people show persistent mathematics difficulties rather than literacy problems in their adulthood (Dowker, 2001; Rivera, 1997). There is also evidence that a high number of adults with mathematics difficulties showed indicators of those problems in early childhood (Dowker, 2001). However, the trend of limited research concerning Specific Learning Disabilities in the area of mathematics seems to have changed in recent years (Rivera, 1997). Based on research results, it is now thought that approximately 6% of today's students are diagnosed with Specific Learning Disabilities in the area of mathematics (Fleischner & Manheimer, 1997). Becker and Selter stated in 1996 (as cited in Klein, Beishuizen, & Treffers, 1998) that "teaching is no longer seen as a treatment and learning as the effect. Learners are people who actively construct mathematics" (p. 443).

Many researchers have proposed hypotheses as to why students are underachievers in mathematics and to account for mathematics Specific Learning Disabilities. Carnine (as cited in Rivera, 1997) has written that he "attributes poor mathematics performance to a 'mismatch' between the design of teaching procedures and curricular materials and the learning characteristics associated with learning disabilities" (p. 8). According to Fleischner and Manheimer (1997), "there are two primary conditions that lead to math underachievement that are associated with learning disabilities. These are primary math learning disabilities and the underachievement in math that may be associated with verbal learning disabilities" (p. 398).

Other research has found links between mathematics achievement, ethnic and racial backgrounds, socioeconomic standards (SES), parental test scores, and home environments (Crane, 1996). Emphasis is also placed on poorly written or confusing texts and poor techniques of instruction (Fleischner & Manheimer, 1997). Several other hypotheses include poor motivation, genetic predisposition, and large deficits in verbal ability (Light, 1995). According to Crane (1996), parents can affect their children's learning of mathematics in three ways: they transmit genes affecting the development of mathematics skills, provide opportunities for exposure to social and cultural activities involving mathematics, and create an environment conducive to the development of those skills.

Allinder (1995) included personal efficacy and teaching efficacy as areas that may affect achievement. Fuchs and Fuchs (1990) found that, when planning for instruction with learning disabled students, the teachers fail to set ambitious goals, underestimate the potential of their students, fail to increase goals, and fail to monitor the progress as often as necessary. Finally, Kasten and Howe (1988) listed five external, as well as internal, reasons for "at-risk" students in mathematics that included the following: cultural differences are not accounted for within the curriculum; females tend to be more at-risk overall because mathematics courses have been frequently seen as a male strength; students may develop "anxieties" that interfere with their performance within mathematics fields; some students are more at-risk due to sensory handicaps, behavior problems, and physical impairments; and the "curriculum and instruction are not appropriate to foster desired attitudes, aspirations, skills, and understandings related to mathematics" (p. 3). Based on overall research results, it is increasingly difficult to determine if the students with poor mathematics achievement are struggling due to an actual learning disability or if other factors are influencing the problems.

Instructional Problems and Suggested Modifications

What modifications can be made by the teachers to help address the problems of the at-risk and Specific Learning Disabled students in mathematics? According to research findings, several actions may be taken to help prevent or reduce poor mathematics achievement and allow students more success in this particular area. First, the schools and teachers can evaluate any problems found with the mathematics instruction itself. According to Kasten and

Howe (1988), instruction problems in mathematics frequently include the following: the classroom routine may not be effective for the students to develop new concepts; the pace of the instruction is incorrect for some students; the technique of "drill and practice" does not prove effective for some students; errors are not properly addressed; and the type of instruction does not include "hands-on experiences" (p.3).

Second, the schools can implement similar mathematics assessment tools to evaluate the students' performance. Assessments in mathematics are important in identifying the strengths and weaknesses of students' in our schools (Bryant & Rivera, 1997; Paulsen, 1997). Mathematics assessments have been repeatedly refined based on the changing mathematics and curriculum content throughout the last century (Bryant & Rivera, 1997).

Third, teachers should use the information obtained from the assessment procedures to help develop effective instructional practices. According to recent research results, a routine of instruction that may work well with one student, or even a few students, may fail to produce the same growth with other students (Whinnery & Stecker, 1992). According to Allinder, Fuchs, Fuchs, and Hamlett (1992), improvement in students' mathematics achievement relies greatly on classroom instruction and practice. The results of their research showed that there must be a "mastery of prerequisite skills prior to instruction on more involved problem types or applications" (Allinder et al., 1992, p. 457). It is important to remember that varying levels of support are necessary to accommodate the needs of the individual students. Students may need to receive intensive special education instruction rather than just changes within the classroom teaching.

Finally, the teachers and school staff should monitor the progress of the students using the procedures in the area of mathematics, and make the necessary modifications if the desired progress is not obtained. Overall, teachers need to hold a vast array of instructional strategies and techniques, and ensure that the progress of the individual student is monitored in order for the student to achieve success.

Present Efforts with Mathematics Special Education

Presently, teachers, both general education and special education, are working in an educational reform culture where federal and state laws and district policies have raised the goals of student achievement (Bottge, Heinrichs, Mehta, & Ya-Hui, 2002). With new state performance standards across the nation, special education teachers must not only help the students with Specific Learning Disabilities increase their achievement and learning levels but they must also meet the new standards set forth from legislation (Bottge et al.). Meeting the new regulation standards, such as federal, state, and district policies, is an area that has proved difficult overall. According to Bottge et al., "Researchers have offered several reasons for this lackluster mathematics performance, including the lack of well-designed intervention studies to validate effective teaching practices, now at their lowest level in 30 years" (p. 186).

Recently many transition models and interventions have been introduced to help increase the level of math performance of the at-risk and Specific Learning Disabled students. In 2001, Bottge et al. developed the Key Model designed to aid individuals with Specific Learning Disabilities with their mathematics activities and understanding. This model acknowledges variables within the student, within the context of the material, and outside influences, such as the environment and teacher factors. Also, many school systems are implementing a procedure called Curriculum Based Measurement (CBM), which allows an evaluation of students' performance and progress in order to compare and use the most effective interventions for each student (Bryant & Rivera, 1997). CBM can also lead to increased school district expectations of students' performance in mathematics.

Furthermore, there have been developments of computer aided instruction (CAI) to help both regular education and special education students. Computer programs are used to help the students increase their practice and understanding of the presented material. Many of the software programs include possibilities for self-monitoring by the student as well as printable scores, thus allowing teachers to monitor progress. Also, teachers are implementing forms of mnemonic interventions and instruction to aid in increasing semantic memory (Greene, 1999). Mnemonic instruction has been shown to be extremely helpful in building the needed foundation skills for more advanced mathematical operations, especially for students with Specific Learning Disabilities, (Greene, 1999). Furthermore, classrooms are supplied with drill cards and worksheets to help increase rote memorization, and manipulatives, games, and small groups with one on one instruction to help the students increase their level of understanding (Greene, 1999).

Overall, research has shown that a substantial number of all individuals experience difficulties with mathematics, which is affecting the numbers of people able to enter technical fields within the workforce (Ridgway & Passey, 1995). The results of the 1992 National Assessment of Educational Progress (NAEP) mathematics assessment show that children and youth in America are significantly deficient in mathematics computation and problem solving abilities (Jitendra & Xin, 1997). Moses (2001) stated that "Sixty percent of new jobs will require skills possessed by only 22 percent of the young people entering the job market now" (as cited in Schoenfeld, 2002, p. 13). This problem of underachievement, of course, is more severe for those students at-risk and with Specific Learning Disabilities in mathematics (Jitendra & Xin, 1997).

Purpose of Research

Considering the importance of mathematics achievement in today's schools and society in general, the current meta-analysis study was conducted to help determine the effects of instruction and strategy implementation on increasing mathematics and computation skills for students with Specific Learning Disabilities.

According to Glass (1976), "Meta-analysis refers to the analysis of analyses . . . the statistical analysis of a large collection of analysis results from individual studies for the purpose of integrating the findings" (p. 3) In other words, meta-analysis is a statistical method of quantitatively integrating the results of independent studies on a specified topic to obtain a single set of numbers to describe and summarize their results. Meta-analyses not only summarize the results of the studies, it also takes into account sample sizes, moderator variables, and effect sizes of the individual studies to provide combined information (Hoffert, 1997). This research approach often leads to a better understanding about a group of seemingly inconsistent studies. It involves the accumulation of effect sizes, which defined by Shaver (1991) is "a metric of the magnitude of a results that is independent of scale of measurement and sample size" (as cited in Yin & Fan, 2000, p. 202).

The present meta-analysis included studies that used the pretest-posttest control group design. This design includes a clear intervention group or groups versus a control or nonintervention group. The decision to include only control group designs was based on the understanding that group designs allow for a more specific determination of a certain intervention's effectiveness. The present meta-analysis focuses more on the overall effects of an intervention rather than the effect of an intervention with one subject. It is expected that the interventions discussed will have a high effect on the mathematics achievement levels of students with Specific Learning Disabilities.

Chapter II

Method and Procedures

Literature Search Procedure and Selection Criteria

First, a computer assisted systematic search for studies was conducted using the following databases: Educational Resources Information Clearinghouse (ERIC), Psychological Abstracts (PSYCLIT), PsycINFO (1887-current), Academic Search Premier, EBSCOhost, Dissertation Abstracts International (DAI), and American Psychological Association (APA) Journal Articles Database. Articles were gathered ranging in dates from 1981 to 2002, and from general education, special education, and psychological journals.

The computer search strategy used the following phrase descriptors: *mathematical ability, meta-analysis and mathematics, mathematics curriculums, mathematics achievement, mathematics performance assessment, mathematics readiness, elementary school mathematics, mathematics instruction, early childhood education, acquisition of basic mathematics skills, numeracy, counting, addition, learning disabilities in the area of mathematics, meta-analysis and mathematics interventions, meta-analysis and mathematics instruction, mnemonic techniques, computer assisted instruction, Curriculum Based Assessment (CBM) and mathematics, elementary school* *students and learning disabilities*, and *pedagogy and mathematics readiness*. Next, once the articles involving mathematics instruction with at-risk students and those with Specific Learning Disabilities were identified, the references cited in these studies were searched for more similar studies.

The criteria for including studies in this meta-analysis were as follows: (a) the participants were elementary (including kindergarten) and/or middle school students; (b) the participants were identified as having a Specific Learning Disability in the area of mathematics, or considered to be at-risk by mathematics achievement performance based on educational performance and teacher/professional judgment; (c) the study investigated the effects of specific mathematics instructional strategies; (d) the study included an experimental and control group for comparison; (e) the study used only one type of intervention versus no intervention rather than two or more intervention approaches; (f) the study used a pretest-posttest control group design; (g) the study reported enough quantitative information regarding outcomes that effect sizes could be calculated; and (h) the study was available in English and was published in a peer-reviewed journal. Considering that only published studies were reviewed, this meta-analysis may include a possible bias for more sound research designs and results that may be found in other unpublished research (Jitendra & Xin, 1997). The studies excluded from this meta-analysis were those that fit into one or more of the following categories: descriptive only, single-subject designs, extension of previous data not able to be obtained, lack of control group, and/or not enough quantitative data to determine an effect size.

Study Characteristics

The literature search and inclusion procedures provided a total of 62 published studies. Once the exclusion procedures were implemented, nine published studies were identified. These nine studies are marked with asterisks in the References section of this meta-analysis. All studies used a pretest-posttest control group design and were found in peer-reviewed journals between 1990 and 2002. Appendix A presents the studies reviewed before the exclusion information was introduced (N = 62). Appendix B presents an overview of the nine studies identified to be included in the meta-analysis data. The review includes four studies that used curriculum-based measurement (CBM) and five that used one of the following: the MASTER program (Van Luit & Naglieri, 1999), the Early Numeracy program

(Van Luit, 2000), Peer Assisted Learning Strategies (PALS) (Fuchs & Fuchs, 1995), and various computer strategies (Stern, 1992). Of the nine studies, there were a total of 744 students (466 with learning disabilities, 49 considered at-risk, 70 with mild to moderate mental disabilities, and 159 considered within the average range overall). Four of the nine studies included students from both elementary and middle school grades. The remaining five included only elementary age participants. Four of the nine studies also reported gender totals, which includes 188 males and 109 girls. Across the nine studies, the length of the interventions varied from 15 weeks to 25 weeks of implementation (Median = 17 weeks). All studies excluding one (Jordan & Montani, 1997) reported an increase in students' mathematics performance following the implementation of the intervention.

Computation of Treatment Effectiveness

Meta-analysis methods do not rely on statistical significance tests. Rather, effect size is used, which measures the magnitude of a treatment effect and leads to more cumulative knowledge (Schmidt, 1995). Effect size estimates may be thought of as the number of standard deviation differences between the means of the groups or times of assessment being compared. The measure of effect size is based on the change of the standard deviation scores. Effect sizes are not influenced by sample sizes. Suggested significant levels of effect size (Cohen's G) are .80 for a large effect, .50 for a medium effect, and .20 for a small effect (Cohen, 1988). The effect size (Cohen's G) in this study was computed as the difference between the mean of the experimental and control posttest groups divided by the mean standard deviation. The effect size is then expressed as a decimal percent of the normal curve standard deviation (Cohen, 1988). All effect sizes reported in the present meta-analysis were calculated on the information from the nine studies. No effect sizes needed to be calculated using t ratios. In order to obtain an overall effect size (Cohen's G) for this study, the difference of the sum of the means of the posttest groups were divided by the sum of the mean pooled standard deviations. The statistical program SPSS 8.0 was used to calculate effect sizes and descriptive statistics.

An effect size was calculated on all dependent variables in each study, with negative signs indicating a lack of higher performance after intervention was implemented. Table 1 shows the individual characteristics of each study used to determine the separate effect sizes. It must be noted that within Study 1 (Van Luit & Naglieri, 1999), a misprint was found and corrected for this analysis. The table from the study listed the comparison group posttest standard deviation as 0.70. When comparing the standard deviations across the remaining areas within

Table 1

Individual Selected Study Characteristics

#	N(E)	N(C)	M(E)	M(C)	S(E)	S(C)
1	42	42	31.90	18.20	5.40	7.00
2	62	62	59.50	53.30	9.30	9.40
3	20	20	6.70	3.71	4.95	5.15
4	10	10	21.14	18.81	8.73	4.92
5	9	12	57.83	40.43	21.00	19.20
6	42	42	32.19	29.81	5.47	6.07
7	10	8	49.85	50.88	18.00	18.05
8	44	44	5.86	5.52	1.68	2.42
9	12	24	83.50	83.50	23.30	23.30

\# = Number of the individual study

N(E) = Number of participants in the experimental group

N(C) = Number of participants in the control group

M(E) = Mean of the experimental group

M(C) = Mean of the control group

S(E) = Standard deviation of the experimental group

S(C) = Standard deviation of the control group

the study and determining possible statistical outcomes, it was determined that this number should have been printed as 7.0. Finally, an overall effect size was then calculated to determine the overall effects of the mathematics interventions throughout the nine studies. The above-mentioned misprinted number was corrected in the calculations of the overall effect size.

Chapter III

Results

All effect sizes were calculated from the reported mean and standard deviation scores reported in each study. These effect size totals are reported in Table 2. Cohen's G scale previously mentioned was used to determine large, medium, and small effect sizes. Across the nine studies, three resulted in a large effect size (Van Luit & Naglieri, 1999; Van Luit, 2000; Allinder, 2000), three resulted in medium effect size (Fuchs & Fuchs, 1995 & 1990; Stecker & Fuchs, 2000), and three resulted in small or no effects (Allinder & Beckbest, 1995; Stern, 1992; Jordan & Montani, 1997). As mentioned previously, suggested significant levels of effect size (Cohen's G) are .80 for a large effect, .50 for a medium effect, and .20 for a small effect (Cohen, 1988).

Overall, Study 1 (Van Luit & Naglieri, 1999) resulted in the largest effect size (Cohen's G = 2.19). This result shows that the MASTER program elicits the highest amount of achievement with students with Specific Learning Disabilities in the area of mathematics. Study 5 (Allinder, 2000) resulted in the second largest effect size (Cohen's G = .87). The effects of combining Curriculum Based Measurement (CBM) with teachers' self-monitoring of the instructional changes for the students showed a high effect size with elementary and middle school students.

Table 2

Standard Deviation and Cohen's G of the Individual Studies

Study #	Standard Deviation Pool	Cohen's G
1	6.25	2.19
2	9.35	0.66
3	5.05	0.59
4	7.09	0.33
5	19.98	0.87
6	5.78	0.41
7	18.02	-.06
8	2.08	0.16
9	23.30	0.00

Table 3 indicates the descriptive statistics of all nine studies combined. These numbers were used to ultimately obtain the overall effect size for the group. Table 3 also indicates the calculation of the overall effect size of all nine studies included in the current meta-analysis. The overall mean effect size was determined to be .57 with a standard deviation of .68. According to Cohen's G scale, this effect size falls within the medium range. The standard deviation is high due to the fact that only nine studies were found that fit the criteria to be included within the meta-analysis.

Table 3

Mean and Standard Deviation of Studies Combined

	Mean	Standard Deviation
Experimental Group Mean	38.719	26.051
Control Group Mean	33.796	25.921
Experimental Group Standard Deviation	10.870	7.855
Control Group Standard Deviation	9.912	8.180
Cohen's G	.5738	.6797

Chapter IV

Discussion of Findings and Summary

The results of the meta-analysis indicated that instruction and strategy implementation can increase mathematics computation skills for students with diagnosed learning problems within classrooms. The overall mean effect size across the nine group design studies was .57. With an overall medium effect size, these results support the view that mathematics techniques training and interventions along with the classroom curriculum are effective in assisting students with Specific Learning Disabilities.

When looking across the individual studies, Study 1 (Van Luit & Naglieri, 1999) produced the highest effect size (Cohen's G = 2.19, SD = 6.25). This result shows that the MASTER program elicits the highest amount of achievement with students with learning disabilities in the area of mathematics. The MASTER program teaches and encourages students to use appropriate mathematics strategies when completing multiplication and division problems. The training program is essentially self-instructed; therefore, the results yield more support to the importance of self-instruction training programs in mathematics (Van Luit & Naglieri, 1999).

Study 5 (Allinder, 2000) shows the second highest effect size (Cohen's G = .87, SD = 19.98). This finding would show that Curriculum Based Measurement (CBM) coupled with teachers' self-monitoring of instructional changes for their students elicits higher amount of achievement. These results support the implementation of CBM along with the teacher's use of monitoring to determine the needed changes for the students' instructions and/or interventions.

The next largest effect size found among the individual studies is Study 2 (Van Luit, 2000). The effect size was still within the large range (Cohen's G = .66, SD = 9.35), according to Cohen's G scale. These results imply that the Early Numeracy Program has a large effect on the achievement of elementary students with learning disabilities in the area of mathematics. This program was developed specifically for young children between five and seven years of age with special education needs. It teaches the students ways to construct meaning and solve simple mathematics problems based on the Perceptual Gestalt Theory. Overall, the results support early mathematics interventions for young elementary children to form a basis for their mathematics instruction in the future.

It is important to note that of the three studies that yielded a large effect size, each supported different types of programs. The programs do not show any type of similarities. This information is valuable because the research presents three different approaches that may be implemented as a means to show an increase in performance of the students struggling with mathematics.

The effect size of three studies are within the medium range (Fuchs & Fuchs, 1995 & 1990; Stecker & Fuchs, 2000). Study 3, (Cohen's G = .59, SD = 5.05), focuses on Peer-assisted Learning Strategies (PALS) with elementary students (Fuchs & Fuchs, 1995). Study 4 (Cohen's G = .33, SD = 7.09) uses performance indicators and skills analysis along with CBM to increase the students' achievement in mathematics (Fuchs & Fuchs, 1990). Finally, Study 6 (Cohen's G = .41, SD = 5.78) also uses the individual progress monitoring aspect of CBM (Stecker & Fuchs, 2000). Note that two of the medium result studies support the use of CBM; however, the third program is not similar in content or implementation.

The final three studies within the meta-analysis (Allinder & Beckbest, 1995; Stern, 1992; Jordan & Montani, 1997) produced little or no effect size. Therefore, the presented programs from Study 7, Study 8, and Study 9 present programs that may not be effective techniques for use with struggling and/or Specific Learning Disabled students in the area of mathematics.

There are some limitations found within the present analysis. First, only published studies were considered for inclusion. As mentioned within the method section, this analysis includes a possible bias for more sound research designs. Next, even though many search engines were used and reference lists were examined for possible articles to include, this analysis was not a completely comprehensive exploration in that an overall hand search of all available journals was not conducted.

While 53 of the 62 published articles did not meet the stringent criteria of the present meta-analysis, the small number of studies included within is a limitation of the previously completed research. Most of the literature and research regarding instruction and strategy implementation in mathematics education focuses on single-subject designs. These designs do not allow for treatment effect sizes to be generalized across groups of students. Within the current meta-analysis, a larger group of studies may have yielded a lower standard deviation. Also, the effect size would be easier to generalize across further studies if the number of studies were larger.

In the future, it is suggested that research be increasingly focused on pretest-posttest group designs rather than single-subject designs when looking at the effect of interventions. With the information across groups, the results can be generalized across classes of students rather than determine feasibility with one student in particular. Also, given the three studies that yielded a large effect size in the current meta-analysis, researchers should look at other studies using the same programs that were designed using a single-subject design. It is possible that previous research using single-subject designs may provide more support for those programs even though the results cannot be generalized. This information would only give more confirmation for the use of the mathematics programs with all students. Future researchers should also study the cost effectiveness for and time consumption needed to implement the three programs in order to present valuable information to schools contemplating their use. Furthermore, increased research of mathematics instruction and strategy programs in general is suggested as a way to obtain overall information regarding students struggling within their classrooms. It is the researchers opinion that the criterion set in the present meta-analysis be used in future research in order to ensure results that may be generalized.

Summary

The effects of the various mathematics instructional approaches to aid students at-risk and with Specific Learning Disabilities are very encouraging. Overall, research has shown that a sizeable number of individuals experience difficulties with mathematics, which affects the numbers of people able to enter technical fields within the workforce (Schoenfeld, 2002). The problem of underachievement in mathematics is more severe for those students at-risk and with Specific Learning Disabilities.

As previously noted, future research studies should address intervention and instruction studies using group designs rather than single-subject designs to give more general results regarding the program. Also, research may be completed using results of the current meta-analysis regarding the three studies with large effect sizes to determine cost effectiveness and time consumption to aid school systems in their decision making process. Furthermore, research should examine ways to allow a direct comparison of treatment effects from both single-subject and group designs so that a generalized finding may be obtainable.

Considering the importance of obtaining mathematics skills in today's schools and society, it is increasingly important that research continue to investigate previously effective and newly developed interventions and ways of instruction to aid these students with the development of mathematics skills. Not only will an increase in their achievement allow the student better understanding and greater opportunities but it will also help to increase their self-esteem and effort level in future areas.

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* References marked with an asterisk indicate studies included in the meta-analysis.

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Appendixes

Appendix A

Titles and Descriptions of Reviewed Articles

TITLE	AUTHOR	YEAR	DESCRIPTION	STATISTICS	RESULTS
Effects of home environment, SES, and maternal test scores on mathematics achievement	Crane, J.	1996	Impact of home environment, SES, and mother cognitive scores on child's math skills	weighted least squares regression	Home environment, SES and maternal scores each had significant effects on achievement
When basic mathematics skills predict nothing: Implications for education and training	Ridgway, J. & Passey, D.	1995	studies the mathematical needs of engineering apprentices – empirical approach to testing the claim that a high level of competence in basic skills is essential to later learning	correlations	successful application of math techniques is essential in engineering; etc.
Students at risk in Mathematics: Implications for Elementary Schools	Kasten, M. & Howe, R. W.	1988	digest provides information for preventing and reducing the problems related to at-risk students	n/a	n/a
Educational assessment of mathematics skills and abilities	Bryant, B. R. & Rivera, D.P.	1997	gives a history of mathematics assessment and offers suggestions for assessment strategies that reflect student progress	n/a	n/a
Students' flexibility in solving two-digit addition and subtraction problems instruction effects	Blote, A. W., et al	2001	examined the influence of instruction on students' understanding of 2-digit addition and subtraction	repeated measures multivariate analyses of variance - doubly multivariate design	the type of instruction made a difference as far as flexibility was concerned, etc.
Effectiveness of the MASTER program for teaching special children multiplication and division	Van Luit, J. E. & Naglieri, J.	1999	examines the effectiveness of a Mathematics Strategy Training for Educational Remediation (MASTER) program for students with poor math skills (LD & MR)	ANOVA; pre-test, post-test	the MASTER program can be effectively employed in teaching multiplication and division to those with MMR and LD
Improving early numeracy of young children with special education needs	Van Luit, J. E.	2000	62 special education kindergarten students were given early mathematics interventions	t tests	they performed better at posttest than the comparison group, but did not transfer info
Effects of acceptability on teachers' implementation of curriculum-based measurement and student achievement in mathematics computation	Allinder, R.M. & Oats, R.G.	1997	Investigates the hyp. That treatment acceptability influences teachers' use of a formative evaluation system and the amount of gain effected in math for the students	one-way ANOVA, t tests	Treatment acceptability offers some insight into the issue of teacher Fidelity in using CBM
Curriculum-based measurement: Translating research into school-based practice	Paulsen, K.J.	1997	step-by-step approach in the development of a customized CBM system for reading and math for elementary schools	n/a	n/a
Acquisition and transfer effects of classwide peer-assisted learning strategies in mathematics for students with varying learning histories	Fuchs & Fuchs	1995	examines the effects of peer-assisted learning strategies in incorporating the use of CBM on the acquisition and transfer learning of three types	one-way ANOVA, chi-square analyses on the nominal data	the PALS implemented effected math achievement across acquisition and transfer measures
Individual progress monitoring to enhance instructional programs in mathematics	Whinnery, K.W. & Stecker, P.M.	1992	tries to identify CBM as one measurement that provides a close link b/w student performance and instructional decisions	n/a	n/a

Classwide decisionmaking with computerized curriculum-based measurement	Fuchs, L.S.	1992	reports on the TN research program that examines the feasibility and utility of 5 types on computer applications to enhance CBM efficacy	n/a	n/a
The role of skills analysis in curriculum-based measurement in math	Fuchs & Fuchs	1990	examines the role of skills analysis in CBM for the purpose of developing more effective instructional programs for math	one-way MANOVA	supports the usefulness of skills analysis within CBM for spec. ed. Teachers
Effects of teacher self-monitoring on implementation of curriculum-based measurement and mathematics computation achievement of students with disabilities	Allinder, R.M.	2000	examines the effects of combining CBM in mathematics computation with teachers' self-monitoring of instructional changes on academic progress of elementary students with LD and MMD	ANOVA with one within-subjects factor and one between-subjects factor	Teachers using the combination of self-monitoring and CBM differed in types of instructional changes and student progress
Effecting superior achievement using CBM: The importance of individual progress monitoring	Stecker, P. M. & Fuchs, L. S.	2000	describes how 22 special ed teachers monitor the math progress of students using CBM	paired t-test, ANOVA	using students' CBM data to decide interventions appears essential for growth
Supplementing teacher judgments of mathematics test accommodations with objective data sources	Fuchs, et al	2000	examines the utility of a data-based assessment process to supplement teacher judgments about test accommodations	ANOVA	mixed results about teacher judgments
Translating research into practice: Preservice teachers' beliefs about CBM	Foegen, A., et al	2001	examines the beliefs of preservice teachers following their viewing of CBM videos	ANOVA	mixed results about teacher beliefs
Classroom assessment data: Asking the right questions	Fox, D.	2000	six questions to ask to ensure decisions are based on sound assessment instruments	n/a	n/a
Curriculum-based assessment procedures embedded within functional behavioral assessments: Identifying escape-motivated behaviors in a general education classroom	Roberts, M. L., et al	2001	examines whether CBA procedures could be incorporated into a FBA to identify antecedent events that occasion off-task classroom behaviors in gen ed classes	interval and frequency recordings	CBA can be used during an FBA as an alternative approach to analogue and functional procedures used during the FBA
Principles for sustaining research-based practice in the schools: a case study	Fuchs & Fuchs	2001	focuses on the effectiveness of Math PALS and methods used for the CBM in these schools	n/a	Personal participation is not necessary to adopt the research-based practice
An examination of the relationship between teacher efficacy and curriculum-based measurement and student achievement	Allinder, R. M.	1995	the relationship b/w personal and teaching efficacy of spec ed teachers, their implementation of CBM and their students' gains in math achievement	ANOVA	Teachers with high personal efficacy and high teaching efficacy increased end-of-year goals more often for their students
Identifying growth indicators for low-achieving students in middle school mathematics	Foegen, A.	2001	explores the technical adequacy of potential indicators of growth in mathematics in middle school	correlations and multiple regressions	the 4 measures are reliable with acceptable criterion validity
Differential effects of two approaches to supporting teachers' use of curriculum-based measurement	Allinder, R. M. & Beckbest, M.A.	1995	investigates the differential effects of two types of follow-up support on use of a data-based instruction system and student achievement	MANOVA	Students in both grps made comparable, significant achievement in math

Formative evaluation of academic progress: how much growth can we expect	Fuchs & Fuchs	1993	examines students' weekly rates of academic growth when CBM is conducted repeatedly over 1 yr.	ANOVA - analysis of relationship b/w slope and grade level	Provides data across years and patterns for different types of measures
Effects of summer break on math and spelling performance as a function of grade level	Allinder, R. M., et al	1992	compares scores on CBM tests administered in the spring and fall	ANOVA	Students in grades 2 & 3 regressed significantly in spelling, but not in math – reverse for grades 4 & 5
Applications in the secondary school mathematics curriculum: a generation of change	Usiskin, Z.	1997	gives history and present work regarding mathematics curriculum in secondary schools	n/a	n/a
Upper elementary school pupils' difficulties in modeling and solving nonstandard additive word problems involving ordinal numbers	Verschaffel, L., De Corte, E., & Vierstraete, H.	1999	data about the scope and the nature of upper elementary school pupils' difficulties with modeling and solving nonroutine additive word problems	analysis of variance with a split plot factorial design, error analysis	a significant effect was found for the number-difference factor – all hypotheses were supported
The empty number line in Dutch second grades: Realistic versus gradual program design	Klein, A.S., Beishuizen, M, & Treffers, A.	1998	compare 2 experimental programs for teaching mental addition and subtraction in the Dutch 2nd grade - RPD vs GPD	paired t-test, ANOVA	there were almost no differences in procedural competence between groups
A longitudinal study of invention and understanding in children's multidigit addition and subtraction	Carpenter, T. P, et al	1997	3-yr study investigated the development of children's understanding of multidigit number concepts and operations	analyses of percentages	Supports the development of understanding before mastery of procedures
Mental strategies and materials or models for addition and subtraction up to 100 in Dutch second grades	Beishuizen, M.	1993	compares strategies on procedural effectiveness and error types and the influence of support conditions	within and between subjects analyses	two strategies were found to be important with extra materials
Instruction on derived facts strategies in addition and subtraction	Steinberg, R.M.	1985	concentrated on facts strategies in which the child uses known number facts to find the solution to unknown number facts	frequency comparisons and t-tests	see discussion – no clear patterns or definitive results
The acquisition of addition and subtraction concepts in grades one through three	Carpenter, T.P. & Moser, J.M.	1984	3-yr study investigated children's solutions to simple addition and subtraction word problems	comparison of interview data	children are not entirely consistent in their choice of strategies
Spontaneous use of conceptual mathematical knowledge in elementary school children	Stern, E.	1992	addresses the question of whether children are able to discover the shortcut strategy but do not use it because they prefer familiar computing strategies	analysis of variance with grouping and repeated variables	children younger than 10 are able to find and use the shortcut strategies under supporting conditions
Extraneous information and extra steps in arithmetic word problems	Muth, K.D.	1992	assessed how middle school students cope with some of the demands imposed on them by arithmetic word problems	analyses of variance with between-subjects factors	extraneous information and extra steps reduce the accuracy of solutions
Item-specific efficacy judgments in mathematical problem-solving: The downside of standing too close to trees in a forest	Marsh, H.W., et al	1997	tests the hypothesis that the failure to include correlated uniquenesses produces bias	analysis of variance and chi-square	Provides evidence for the effects of including correlated uniqueness
Teaching addition and subtraction with regrouping to educable mentally retarded children: A group self-instructional training program	Whitman, T & Johnston, M.B.	1983	examines the effectiveness of a self-instructional training program for teaching math computation skills to educable mentally retarded children	comparison of data	self-instructional training procedure implemented in a group setting can be effectively employed

The effects of back-to-basics on mathematics education	Cheek, H.N. & Castle, K.	1981	discusses the back-to-basics movement and its influence on achievement	n/a	n/a
Preferred model selection in the validation of scales involving hierarchical dependencies among learning tasks	Bergan, J.R.	1980	examines the test performance of 100 children on subtraction tasks involving variations in borrowing	Pearson Chi-square / likelihood-ratio statistic	tasks including various types of borrowing were equivalent and that ability to subtract w/out borrowing was prerequisite
Children's difficulties in subtraction: Some causes and questions	Baroody, A.J.	1984	outlines a model of subtraction development and the computing difficulties and research issues suggested by the model	n/a	n/a
Instruction supporting children's counting on for addition and counting up for subtraction	Fuson, K.C. & Fuson, A.M.	1990	provides data concerning children's accuracy and reports pretest and posttest data with regard to an earlier study on addition and subtraction	n/a	n/a
Lack of automaticity in the basic addition facts as a characteristic of arithmetic learning problems and instructional needs	Cumming, J.J. & Elkins, J.	1999	examines computational facility and the relationship between automaticity or efficient processing of addition facts and success in more complex tasks	means and standard deviations of latencies	performance on multidigit addition sums was related to/dependent on processing efficiency
Numeracy recovery: a pilot scheme for early intervention with young children with numeracy difficulties	Dowker, A.	2001	pilots the Numeracy Recovery scheme with children identified as having problems with arithmetic	evaluates mean scores	project still in early stages – first 62 children showed significant improvement following the interventions
Effectiveness of a cognitive strategy intervention in improving arithmetic computation based on the PASS theory	Naglieri, J.A. & Johnson, D.	2000	determines if an instruction designed to facilitate planning would have differential effects depending on the specific PASS cognitive characteristics of each child	percentages of performance comparisons and effect sizes	children with a cognitive weakness in Planning improved considerably
Validated practices for teaching mathematics to students with learning disabilities: a review of the literature	Miller, S.P. et al	1998	provides an updated literature review related to math practices for students with learning disabilities	n/a	n/a
Which mental strategies in the early number curriculum? A comparison of British ideas and Dutch views	Beishuizen, M.	1998	presents views and research evidence from the Netherlands	n/a	n/a
Mathematical word-problem-solving instruction for students with mild disabilities and students at risk for math failure: a research synthesis	Jitendra, A. & Xin, Y. P.	1997	reviews published research on mathematical word-problem-solving instruction - summarizes intervention studies	n/a	with the exception of one study, all studies reported positive effects of interventions
Mathematics education and students with learning disabilities: introduction to the special series	Rivera, D. P.	1997	provides an overview of trends in the fields of mathematics and special education	n/a	n/a
Students' development of length concepts in a logo-based unit on geometric paths	Clements, D.H. & Battista, M.T.	1997	investigates the development of linear measure concepts within an instructional unit on paths and lengths of paths	means and standard deviations	observed three levels of strategies for solving different length problems

Math interventions for students with learning disabilities: myths and realities	Fleischner, J.E. & Manheimer, M.A.	1997	describes instructional techniques that are effective in helping students with specific learning disabilities in mathematics	n/a	n/a
Calculation abilities in young children with different patterns of cognitive functioning	Jordan, N.C., et al	1995	Examines the arithmetic calculation abilities of kindergarten and first grade children with different patterns of cognitive functioning	MANOVA with ability group and grade as between-Ss factors and problem type as within-Ss factor	verbal facility may be helpful but not necessary for developing calculation skills
The effects of computer-assisted versus teacher-directed instruction on the multiplication performance of elementary students with learning disabilities	Wilson, R. & Majsterek, D.	1996	Examines the effects of two types of instruction of the multiplication performance of elementary students with learning disabilities	single subject alternating treatments design	consistent trends favoring the teacher-directed condition on fact mastery
Cognitive arithmetic and problem solving: a comparison of children with specific and general mathematics difficulties	Jordan, N.C. & Montani, T.O.	1997	Examines problem-solving and number fact skills in children with mathematics difficulties	ANOVA	children with specific MD have deficits in fact retrieval and children with general MD have more basic delays with conceptualization and execution
Can I balance arithmetic instruction with real-life math?	Burns, M.	1998	outlines the importance of teaching arithmetic and shows how to match instruction to real-life events	n/a	n/a
Interpreting the standards	Schifter, D.E. & O'Brien, D.C.	1997	Explains how the principles of teaching mathematics should be put to practice in the classroom	n/a	n/a
Student gender and teaching methods as sources of variability in children's computational arithmetic performance	Hopkins, K.B. & Lisi, A.M.	1997	Studies the effect of a didactic and a contructivist teaching approach on gender differences in mathematics performance in the classroom	ANOVA	significant interaction between gender and instruction group found
Mnemonic multiplication fact instruction for students with learning disabilities	Greene, G.	1999	Examines the application of instruction in learning mathematics for elementary students with learning disabilities	within-Ss counter-balanced design	supports the view that mnemonic training contributes more to the retention of math facts than traditional
Rote vs. rules: a comparison of two teaching and correction strategies for teaching basic subtraction facts	Van Houten, R.	1993	Experiments whether children who had demonstrated difficulty in learning subtraction facts by rote could learn using a simple rule	means and standard deviations	children with a learning disability learned subtraction facts more rapidly when taught with a rule rather than traditional drill
Number sense: rethinking arithmetic instruction for students with mathematical difficulties	Gersten, R. & Chard, D.	1999	Demonstrates how the number sense concept can offer a framework for conceptualizing interventions	n/a	n/a
Mathematics interventions and students with high-incidence disabilities	Cawley, J.F.	2002	Describes two measures of arithmetic facts and problem solving with SLD students	n/a	n/a
The long-term effects of small classes in early grades: lasting benefits in mathematics achievement at grade 9	Nye, B., et al	2001	Reports analyses of a 6-yr follow-up of the students in an experiment in Texas	ANOVA	the positive effects of small classes in early grades resulted in mathematics achievement gains

Children's conceptual structures for multidigit numbers and methods of multidigit addition and subtraction	Fuson, K.C. & Wearne, D.	1997	Report progress regarding children's conceptions of multidigit numbers and their uses	n/a	n/a
Weighing the benefits of anchored math instruction for students with disabilities in general education classes	Bottge, B.A., et al	2002	Examines the effectiveness of enhanced anchor instruction and traditional problem instruction in improving the performance of students with and without disabilities	ANCOVA and repeated measures	EAI students outperformed TPI students on the conceptualized posttest and the transfer test

Appendix B

Titles and Descriptions of Included Studies

TITLE & STUDY #	AUTHOR	YEAR	DESCRIPTION	RESULTS	Type
Effectiveness of the MASTER program for teaching special children multiplication and division (1)	Van Luit & Naglieri	1999	Examines the effectiveness of a Mathematics Strategy Training for Educational Remediation (MASTER) program for students with poor math skills	the MASTER program can be effectively employed in teaching multiplication and division to children with MMR and LD	control vs experimental groups - MMR age m=12, 8 - LD age m=10, 10
Improving early numeracy of young children with special education needs (2)	Van Luit	2000	62 special education kindergarten students were given early mathematics interventions	they performed better at posttest than the comparison group, but did not transfer their knowledge	control vs experimental groups - 62 ages 5-7
Effects of acceptability on teachers' implementation of CBM and student achievement in mathematics computation (3)	Allinder & Oats	1997	Investigates the hyp. that treatment acceptability influences teachers' use of a formative evaluation system and the amount of gain effected in math for the students	treatment acceptability offers some insight into the issue of teacher fidelity in using CBM	compared "high acceptability" vs "low acceptability" teachers
The role of skills analysis in curriculum-based measurement in math (4)	Fuchs & Fuchs	1990	Examines the role of skills analysis in CBM for the purpose of developing more effective instructional programs for math	Supports the usefulness of skills analysis within CBM for spec. ed. Teachers	3 grps (CBM w/performance indicator, PI only, control) - CBM had 4 students, control had 2 - grades 3-9
Effects of teacher self-monitoring on implementation of CBM and mathematics computation achievement of students with disabilities (5)	Allinder	2000	Examines the effects of combining CBM in mathematics computation with teachers' self-monitoring of instructional changes on academic progress of elementary students with LD and MMD	Teachers who used the combination of self-monitoring and CBM differed in the types of instructional changes and students made more progress	3 grps (CBM only, CBM w/self-monitoring, control)
Effecting superior achievement using CBM: The importance of individual progress monitoring (6)	Stecker & Fuchs	2000	Describes how 22 special ed teachers monitor the math progress of students using CBM	using students' CBM data to decide instructional interventions appears essential for growth	CBM target student vs partner
Differential effects of two approaches to supporting teachers' use of curriculum-based measurement (7)	Allinder & Beckbest	1995	Investigates the differential effects of two types of follow-up support on use of a data-based instruction system and student achievement	Students in both grps made comparable, significant achievement in math	consultant grp vs self-monitoring (trmt) grp
Spontaneous use of conceptual mathematical knowledge in elementary school children (8)	Stern	1992	Addresses the question of whether children are able to discover the shortcut strategy but do not use it b/c they prefer to use more familiar computing strategies	Children younger than 10 are able to discover and use the shortcut strategies under supporting conditions	supporting vs control condition

TITLE & STUDY #	AUTHOR	YEAR	DESCRIPTION	RESULTS	Type
Cognitive arithmetic and problem solving: a comparison of children with specific and general mathematics difficulties (9)	Jordan & Montani	1997	Examines problem-solving and number fact skills in children with mathematics difficulties	Children with specific MD have deficits associated with fact retrieval; children with general MD have more basic delays with problem conceptualization and execution	data split into ability group and condition and compared